

EDITORIAL COMMENT

Intracoronary Electrocardiogram

A Free and Underexploited Diagnostic Tool in Angioplasty*

Bernhard Meier, MD

Animal studies on the intracoronary electrocardiogram (IC ECG) preceded coronary angioplasty, today referred to as percutaneous coronary intervention (PCI), by 1 year, almost 40 years ago (1). Even the balloon was there, but it was used for temporary coronary occlusion producing ischemia rather than for treating coronary stenoses.

In 1983, pacemaker electrodes were used to derive an intracardiac ECG in patients with various degrees of ischemia (2).

In 1984, IC ECG was first used in patients. This happened in the realm of PCI (3). When hooking up the coronary guidewire to equipment for coronary pacing to obviate the need for a temporary right ventricular pacemaker, it was found that simultaneous connection to the precordial input socket of any ECG machine revealed a continuous I.C. ECG (4). This not only reflected by definition the territory of interest but also showed ischemia much more conspicuously (and therefore conceivably sooner) than even the precordial leads. The I.C. ECG appeared particularly helpful in the territory of a nondominant left circumflex coronary artery, notoriously poorly represented by standard ECG leads (Figure 1).

These findings were confirmed in further clinical papers (5-7). The poor representation of the territory of the left circumflex coronary artery in the traditional 12-lead ECG (Figure 1) was again highlighted in 1989 when the I.C. ECG was examined in the role of the gold standard for regional myocardial ischemia during PCI. The I.C. ECG excelled indeed due to the unfavorable traditional external lead position. Ischemia in the I.C. ECG, but not in the traditional leads, was identical in

the territories of all left coronary arteries (8). This was again nicely shown in 1991 (9).

The fact that looking at the ECG was like using a magnifying glass to look at a standard lead was used in a paper to analyze the triggering of a torsade des pointes by papaverine in a patient during I.C. ECG recording (10).

Further processing of the I.C. ECG signal was first recommended in 1989 (11). This has now been taken to a higher, more sophisticated level by an Italian group in this issue of *JACC: Cardiovascular Interventions* (12).

SEE PAGE 988

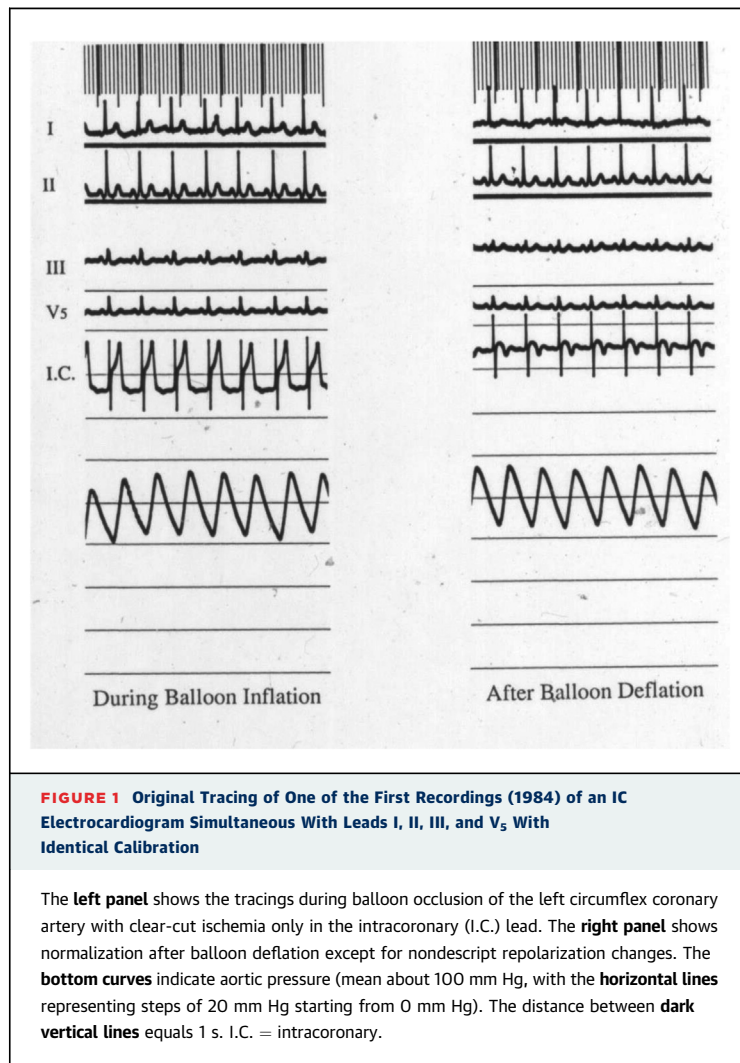
Technical papers in the early '90s showed that some repolarization changes in the I.C. ECG as seen in Figure 1 were not necessarily signs of ischemia but rather signs of the proximity of the lead to the muscle (13) and that there may be a repolarization alternans undetectable by surface ECG leads (14).

In this millennium, the I.C. ECG was used to predict myocardial recovery during primary PCI (15,16). Viability assessment in stable patients in comparison with stress echocardiography (17) or with balloon occlusion (18) and predictability of protection by recruitable collaterals (19) using the I.C. ECG were further applications proposed. These reports added to the few, but seminal, papers correlating the I.C. ECG with clinical and prognostic endpoints in coronary artery disease. Last, but not least, I.C. ECG was correlated with fractional flow reserve in an interesting attempt to obviate the need for the costly pressure wire (20).

The electrophysiology guild showed interest in I.C. ECG, an instrument that seems predestined for electrocardiographic mapping, in 2006 with a paper that used the I.C. ECG for the work-up of ventricular tachycardia (21). Finally, joining forces of electrophysiologists, interventional cardiologists, bio-engineers, and statisticians generated the sophisticated paper in this issue on correlating viability assessment with magnetic resonance imaging to the I.C. ECG derived from territories beyond chronic total

*Editorials published in *JACC: Cardiovascular Interventions* reflect the views of the authors and do not necessarily represent the views of *JACC: Cardiovascular Interventions* or the American College of Cardiology.

From the Cardiovascular Department, University Hospital Bern, Bern, Switzerland. Dr. Meier has reported that he has no relationships relevant to the contents of this paper to disclose.



occlusion (CTO) (12). Even when it does not sound very practical to first have to pass a coronary guidewire and then even have to also advance an insulation catheter through a CTO to focus the electrical harvesting region to the very territory of interest before being able to assess viability, the paper has significant clinical value. The correlation with magnetic resonance imaging, the only defensible (radiation-free) gold standard for myocardial viability assessment, is new for the I.C. ECG and quite convincing.

The clinical work-up of patients with a CTO and echocardiographic or angiographic evidence of regional dysfunction of the left ventricle corresponding to the coronary artery with the CTO should continue to go down the path of magnetic resonance imaging viability assessment unless clinical symptoms are compelling. However, there are situations in the catheterization laboratory where the approach proposed here comes in handy.

Assume a patient has had a myocardial infarction without access to primary PCI and now undergoes elective coronary angiography a few weeks later without any prior noninvasive test looking for ischemia and without a clear-cut history of residual angina. This should not happen according to the guidelines, but it does. A short occlusion of a major coronary artery with visible collaterals is then found, but the respective territory appears akinetic. The likelihood of being able to pass this occlusion quite easily with a guidewire for I.C. ECG is at least 90%. Whether it is really necessary to add an insulation catheter is debatable. A swift angioplasty operator would probably use a balloon catheter for this, and the lesion would be dilated anyway, rather than just tunneled with the insulation catheter. Once accustomed to the setup described in the paper, it will be a matter of minutes to get the wire connected to the electrophysiological recorder and to apply the signal treatment recommended. A fairly accurate assessment is immediately available in real time about the potential recoverability of myocardial function in this territory. A large area of apparently fully viable myocardium will justify the investment of even several stents, whereas no viability will argue against PCI altogether. What if the CTO is difficult to pass and significant time and material has to be invested to finally get across it? In this case, it seems to make sense to recanalize the vessel anyway. This does not mean that simultaneous assessment of viability with the I.C. ECG should not be done.

Bear in mind what is recommended here imparts no additional radiation to the patient if a recanalization attempt was going to be attempted anyway, even without available proof of viability. It consumes no added material and practically no time, and it harbors no additional risk. It avoids the use of a complex additional diagnostic procedure (viability testing by magnetic resonance imaging), let alone poorly invested irradiation when radioactive tracers are used to test for viability with scintigraphy or positron emission tomography. Stress echocardiography might be the only competitor for this I.C. ECG protocol because transthoracic echocardiography is quite applicable during diagnostic catheterization.

Notwithstanding, we have to remain realistic about the place this technique is likely to attain in PCI. The past 30 years have shown that the I.C. ECG is as readily forgotten as it is available.

REPRINT REQUESTS AND CORRESPONDENCE: Dr. Bernhard Meier, Cardiovascular Department, University Hospital Bern, Freiburgstrasse, 3010 Bern, Switzerland. E-mail: bernhard.meier@insel.ch.

REFERENCES

1. Hashimoto K, Corday E, Lang TW, et al. Significance of S-T segment elevations in acute myocardial ischemia. Evaluation with intracoronary electrode technique. *Am J Cardiol* 1976; 37:493-500.
2. Donaldson RM, Taggart P, Swanton H, Fox K, Noble D, Rickards AF. Intracardiac electrode detection of early ischaemia in man. *Br Heart J* 1983;50:213-21.
3. Meier B, Killisch JP, Adatte JJ, Casalini P, Rutishauser W. Intracoronary electrocardiography during transluminal coronary angioplasty. *Schweiz Med Wochenschr* 1985;115:1590-3.
4. Meier B, Rutishauser W. Coronary pacing during percutaneous transluminal coronary angioplasty. *Circulation* 1985;71:557-61.
5. Friedman P, Shook T, Kirshenbaum J, Selwyn A, Ganz P. Value of the intracoronary electrocardiogram to monitor myocardial ischemia during percutaneous transluminal coronary angioplasty. *Circulation* 1986;74:330-9.
6. Feldman T, Chua K, Childers R. R wave of the surface and intracoronary electrogram during acute coronary artery occlusion. *Am J Cardiol* 1986;58:885-90.
7. Piovaccari G, Marzocchi A, Marrozzini C, Maresta A, Magnani B. Valutazione del tempo di comparsa dell'ischemia miocardica durante angioplastica coronarica: confronto fra elettrogramma intracoronarico ed elettrogramma di superficie [Evaluation of the time of appearance of myocardial ischemia during coronary angioplasty: comparison of the intracoronary electrogram and surface electrogram]. *Cardiologia* 1987;32:1119-23.
8. Berry C, Zalewski A, Kovach R, Savage M, Goldberg S. Surface electrocardiogram in the detection of transmural myocardial ischemia during coronary artery occlusion. *Am J Cardiol* 1989;63:21-6.
9. Piessens J, Vrolix M, Sionis D, Glazier JJ, De Geest H, Willems J. The value of the intracoronary electrogram for the early detection of myocardial ischaemia during coronary angioplasty. *Eur Heart J* 1991;12:1176-82.
10. Jain A, Jenkins MG. Intracoronary electrocardiogram during torsade des pointes secondary to intracoronary papaverine. *Cathet Cardiovasc Diagn* 1989;18:255-7.
11. Taggart P, Sutton P, John R, Hayward R, Swanton H. The epicardial electrogram: a quantitative assessment during balloon angioplasty incorporating monophasic action potential recordings. *Br Heart J* 1989;62:342-52.
12. Petrucci E, Balian V, Bocchieri A. Real-time assessment of myocardial viability in the catheterization laboratory using the intracoronary electrograms recorded by the PTCA guidewire in patients with left ventricular dysfunction: comparison with delayed-enhancement magnetic resonance imaging. *J Am Coll Cardiol Interv* 2014;7:988-96.
13. Jain A, Jenkins MG, Gettes LS. Lack of specificity of new negative U waves for anterior myocardial ischemia as evidenced by intracoronary electrogram during balloon angioplasty. *J Am Coll Cardiol* 1990;15:1007-11.
14. Kwan T, Feit A, Chadow H, et al. Intracoronary ST-T alternans during coronary balloon angioplasty. *Cathet Cardiovasc Diagn* 1995;35:121-6.
15. Yajima J, Saito S, Honye J, Takayama T, Ozawa Y, Kanmatsuse K. Intracoronary electrocardiogram for early detection of myocardial viability during coronary angioplasty in acute myocardial infarction. *Int J Cardiol* 2001;79:293-9.
16. Balian V, Galli M, Repetto S, et al. Intracoronary ST segment evolution during primary coronary stenting predicts infarct zone recovery. *Catheter Cardiovasc Interv* 2005;64:53-60.
17. Abaci A, Oguzhan A, Topsakal R, et al. Intracoronary electrocardiogram and angina pectoris during percutaneous coronary interventions as an assessment of myocardial viability: comparison with low-dose dobutamine echocardiography. *Catheter Cardiovasc Interv* 2003;60: 469-76.
18. Uetani T, Amano T, Kumagai S, et al. Intracoronary electrocardiogram recording with a bare-wire system: perioperative ST-segment elevation in the intracoronary electrocardiogram is associated with myocardial injury after elective coronary stent implantation. *J Am Coll Cardiol Interv* 2009;2: 127-35.
19. Meier P, Gloekler S, Zbinden R, et al. Beneficial effect of recruitable collaterals: a 10-year follow-up study in patients with stable coronary artery disease undergoing quantitative collateral measurements. *Circulation* 2007;116:975-83.
20. Balian V, Marcassa C, Galli M, et al. Intracoronary electrocardiogram ST segment shift evaluation during intravenous adenosine infusion: a comparison with fractional flow reserve. *Cardiol J* 2011;18:662-7.
21. Kumagai K, Takahashi A, Yamauchi Y, Aonuma K. Ventricular tachycardia originating from the epicardium identified by intracoronary mapping using a PTCA guidewire. *J Cardiovasc Electrophysiol* 2006;17:670-3.

KEY WORDS intracoronary electrocardiogram, magnetic resonance, percutaneous coronary intervention